P 29. Theoretical modelling of laser welding of Ni – Pt spark plug for bio-fuel engine

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The interaction of laser beam with dissimilar metals during welding process was studied theoretically. A finite element based three-dimensional transient heat transfer and fluid flow model was applied for prediction temperature distribution and material mixing field as well as weld dimensions. The model was used for study and optimization process parameters of welding of Ni – Pt spark plug for bio-fuel engine. The laser pulse duration and energy, and the angle of incidence of the laser beam to the surface were analyzed. The shape of the melting pool obtained from the theoretical model was close to experimental results.

1. Introduction

The development of long life spark plug has become essential in response to the future bio-fuel engine revolution tasks. To achieve these tasks, the electrode tips should be covered with a pad made of special alloys of platinum or iridium, which have better resistance to erosion in high temperature. Recently, the laser welding has been actively developed as a method of coupling the electrode tip with the central electrode [1,2]. Nevertheless, theoretical model of the welding process is a useful and cost lowering tool providing guidance for selection of parameters. Experiments are expensive and time consuming due to the high cost of iridium or platinum pads, as well as the need to carry numerous attempts to obtain a reliable connection. Presented model has been successfully used to verification and optimization of laser welding of spark plug for bio-fuel engine.

2. Mathematical model

The model has been built and was solved by Ansys-Fluent [3, 4]. From two models of species segregation at the micro-scale offered by Ansys-Fluent the Scheil rule was selected.
In the considered case the energy source is stationary. Two different models/cassis one for process parameters and second to verification of experiment are studied. In the case of optimization process the angle of incidence of the laser beam to the surface of the sample is equal 45˚. The focused beam of Nd-YAG laser operating at a wavelength of 1064 nm has Gaussian intensity distribution (fundamental mode), and the diameter of the focus is 0.25 mm. The single rectangular laser pulse duration width 20 ms, and energy 8 J is used. For verification of experiment process laser parameters 0.7 mm, 1.5 ms and 4.6 J are adopted respectively. The laser beam is parallel to axis of spark plug and irradiates both materials at the same time. All material properties of nickel and platinum assumed for the calculations are dependent on temperature.

3. Results

On the basis of the temperature distribution and the liquid fraction phase (Fig. 1) it can be deduced, that energy of impulse in experiment was too high. It caused significant remelting of platinum pad and displacement of melted material toward boundary of electrode. It resulted in deformation of platinum pad surface and creation of air gap (Fig. 1b), which may cause decrease of resistance to erosion. The melted zone in the place of connection of nickel electrode with platinum pad is minor (Fig. 1c). The numerical results obtained for liquid fraction indicates that better results should be obtained at different laser beam position, i.e. irradiated on the contact of pad and electrode at an angle such as 45 degrees, and a reduction of laser beam focus diameter. The displacement of laser beam position should cause the development of melted zone in the place of contact of the electrode and the pad

instead the front of the pad. The surface temperature of the pad and the electrode exceed boiling point of platinum and nickel respectively (Fig. 1a).

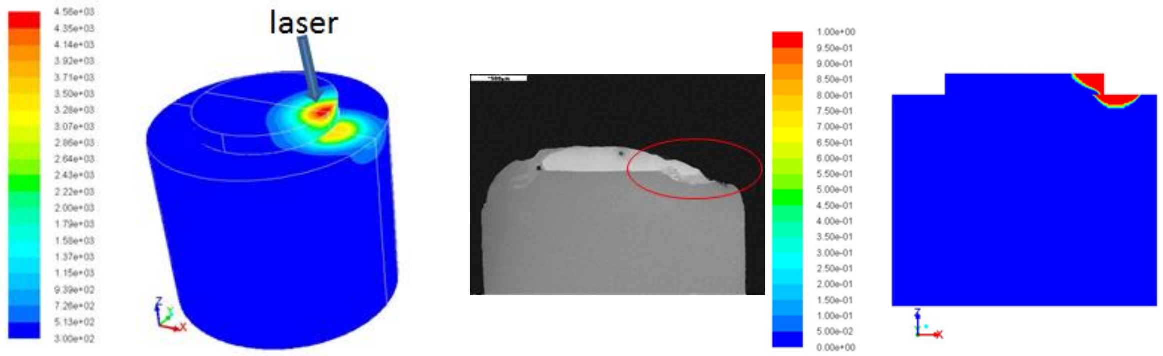

Fig. 1. Verification of experiment: a) surface temperature, b) cross section of spark plug, c) liquid fraction after cessation of impulse.

The temperature distribution suggests the change of the impulse energy and the widening of impulse duration, and the reduction of laser beam focus diameter. The results of optimization are shown in Figure 2. The regular melting zone and the pad surface without deformation are obtained. The widening of impulse duration allowed provide bringing more energy to the sample and thus increasing size of the melting zone. The proper localization and decreasing of size of the laser spot allowed focusing laser beam at the desired location without excessive damaging of the pad surface and the electrode. The temperature inside the weld does not exceed boiling temperature of nickel, which may affect in the reduction of the defects in it.

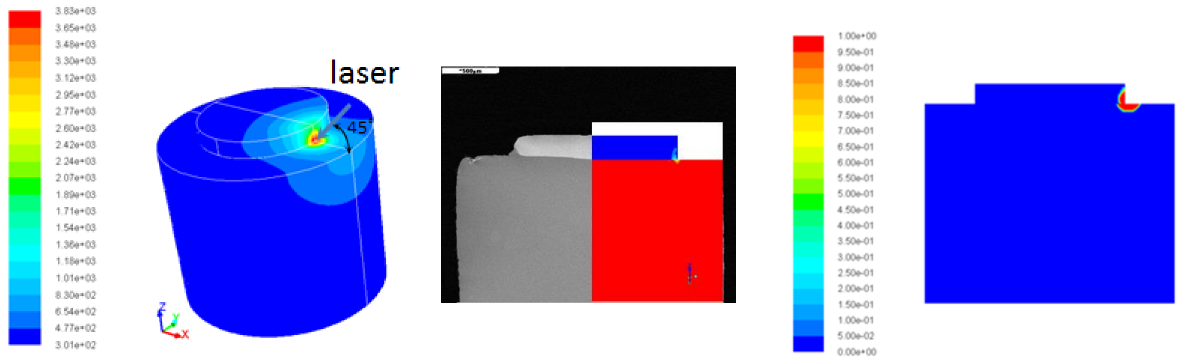

Fig. 2. Optimization of experiment: a) surface temperature, b) cross section of spark plug with theoretical content of species (red – Ni, blue – Pt), c) liquid fraction after cessation of impulse.

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